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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : E21B 44/00 — A2

(11) International Publication Number: WO 98/17894

(43) International Publication Date: 30 April 1998 (30.04.98)

(21) International Application Number: PCT/US97/20294

(22) International Filing Date: 22 October 1997 (22.10.97)

(30) Priority Data:

08/734,935	22 October 1996 (22.10.96)	US
PCT/US96/17106	23 October 1996 (23.10.96)	WO
(34) Countries for which the regional or international application was filed:		AT et al.
60/521,614	27 June 1997 (27.06.97)	US

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

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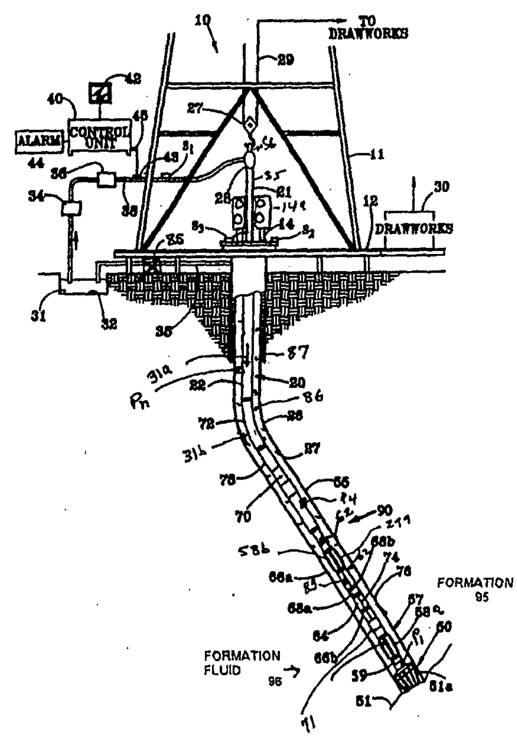
(54) Title: DRILLING SYSTEM WITH INTEGRATED BOTTOM HOLE ASSEMBLY

(57) Abstract

The present invention provides a drilling system (10) that utilizes an integrated bottom hole assembly (90). The bottom hole assembly contains sensors (59, S1–S6, 64, 76, 74) for determining the health of the bottom hole assembly, borehole condition, formation evaluation characteristics, drilling fluid physical and chemical properties, bed boundary conditions around and in front of the drill bit, seismic maps and the desired drilling parameters that include the weight on bit, drill bit speed and the fluid flow rate. A downhole processor (70) controls the operation of the various devices in the bottom hole assembly to effect changes to the drilling parameters and the drilling direction to optimize the drilling effectiveness.



TITLE: DRILLING SYSTEM WITH INTEGRATED BOTTOM HOLE ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field Of The Invention

This invention relates generally to systems for drilling oilfield wellbores and more particularly to an integrated bottom hole assembly (BHA) for use in drilling wellbores. The BHA includes a drill bit and a variety of devices, sensor and interactive models. The BHA tests and calibrates sensors, and determines the operating condition of devices, formation parameters, wellbore condition, and the condition of the drilling fluid. The BHA utilizing such information and the models determines the desired operating parameters that will provide enhanced overall drilling performance and longer BHA operating life. The BHA takes actions to control the drilling operations based the computed parameters or upon command from the surface or a both and in accordance with a higher logic provided to the BHA, thereby improving the overall effectiveness of the drilling operations.

2. Description Of The Related Art

Oilfield wellbores are formed by rotating a drill bit carried at an end of an assembly commonly referred to as the bottom hole assembly or "BHA." The BHA is

conveyed into the wellbore by a drill pipe or coiled-tubing. The rotation of the drill bit is effected by rotating the drill pipe and/or by a mud motor depending upon the tubing used. For the purpose of this invention, BHA is used to mean the bottom hole assembly with or without the drill bit. Prior art bottom hole assemblies generally include one or more formation evaluation sensors, such as sensors for measuring the resistivity, porosity and density of the formation. Such bottom hole assemblies also include devices to determine the BHA inclination and azimuth, pressure sensors, temperature sensors, gamma ray devices, and devices that aid in orienting the drill bit a particular direction and to change the drilling direction. Acoustic and resistivity devices have been proposed for determining bed boundaries around and in some cases in front of the drill bit.

In practice, the bottom hole assemblies are manufactured for specific applications and each such version usually contains only a selected number of devices and sensors. Additionally, such BHA's have limited data processing capabilities and do not compute the parameters downhole that can be used to control the drilling operations. Instead, such bottom hole assemblies transmit data or partial answers uphole via a relatively small data-rate telemetry system. The drilling decisions are made at the surface based on the information provided by the BHA, data gathered during drilling of prior wellbores, and geophysical or seismic maps of the field. Drilling parameters, such as the weight-on-bit, drilling fluid flow rate, drill bit r.p.m. are usually measured and controlled at the surface. The prior art

bottom hole assemblies do not provide a comprehensive or integrated approach to drilling wellbores as more fully explained below.

The operating or useful life of the drill bit, mud motor, bearing assembly, and other elements of the BHA depends upon the manner in which such devices are operated and the downhole conditions. This includes rock type, drilling conditions such as pressure, temperature, differential pressure across the mud motor, rotational speed, torque, vibration, drilling fluid flow rate, force on the drill bit or the weight-on-bit ("WOB"), type of the drilling fluid used and the condition of the radial and axial bearings.

Operators often tend to select the rotational speed of the drill bit and the WOB or the mechanical force on the drill bit that provides the greatest or near greatest rate of penetration ("ROP"), which over the long run may not be most cost effective method of drilling. Higher ROP can generally be obtained at higher WOB and higher rpm, which can reduce the operating life of the components of the BHA. If any of the essential BHA component fails or becomes relatively ineffective, the drilling operation must be shut down to pull out the drill string from the borehole to replace or repair such a component. Typically, the mud motor operating life at the most effective power output is less than those of the drill bits. Thus, if the motor is operated at such a power point, the motor may fail prior to the drill bit This will require stopping the drilling operation to retrieve and repair or replace the motor.

WHAT IS CLAIMED IS:

1. A bottom hole assembly ("BHA") for use in drilling an oilfield wellbore, comprising:

   (a) a plurality of sensors disposed in the BHA, each said sensor making measurements during the drilling of the wellbore relating to a parameter of interest;

   (b) a plurality of interactive models in the BHA, each said model adapted to manipulate data downhole; and

   (c) a processor in the BHA, said processor utilizing the interactive models to manipulate the measurements from the plurality of sensors to determine a plurality of parameters of interest downhole during the drilling of the wellbore.

2. The bottom hole assembly of claim 1, wherein the sensors in the BHA are selected from a group consisting of (a) drill bit sensors, (b) sensors which provide parameters for a mud motor, (c) BHA condition sensors, (d) BHA position and direction sensors, (e) borehole condition sensors, (f) an rpm sensor, (g) a weight on bit sensor, (h) formation evaluation sensors, (i) seismic sensors, (j) sensors for determining boundary conditions, (k) sensors which determine the physical properties of a fluid in the wellbore, and (l) sensors that measure chemical properties of the wellbore fluid.

3. The bottom hole assembly of claim 1, wherein the parameters of interest are selected from a group consisting of (a) health of selected BHA components, (b) mud motor parameters, including mud motor stator temperature, differential pressure across a mud motor, and fluid flow rate through a mud motor, (c) BHA condition parameters including vibration, whirl, radial displacement, stick-slip, torque, shock, vibration, bending moment, bit bounce, axial thrust, and radial thrust, (d) BHA position parameters, including BHA azimuth, BHA coordinates, BHA inclination and BHA direction, (e) a boundary location relative to the BHA, (f) formation parameters, including resistivity, dielectric constant, water saturation, porosity, density and permeability (f) borehole parameters, including borehole size, and borehole roughness, (g) geophysical parameters, including acoustic velocity and acoustic travel time, (h) borehole fluid parameters, including viscosity, density, clarity, rheology, pH level, and gas, oil and water contents, (i) a boundary condition, (j) physical properties of the borehole fluid, (k) chemical properties of the borehole fluid, (l) drilling parameters, including weight on bit, rate of penetration, drill bit r.p.m. and fluid flow rate, and (m) estimate of the remaining operating life of a BHA component.

4. The bottom hole assembly of claim 1, wherein the processor further performs an in-situ test of at least one sensor in the BHA to measure any error in the measurements of such sensor and in response to such measured error makes

corrections by one of (a) calibrating the sensor prior to utilizing any measurement from such sensor, (b) correcting the measurement of the sensor before processing the measurements from such sensor, and (c) correcting any parameter of interest determined from the measurement of such sensor.

5. The bottom hole assembly of claim 1 further comprising a downhole controlled steering device.

6. The bottom hole assembly of claim 5, wherein said plurality of parameters of interest includes a desired drilling direction and the processor adjusts the steering device to cause the BHA to drill the wellbore in the desired direction.

7. The bottom hole assembly of claim 1, wherein the processor turns on and turns off sensors in the BHA according to a predetermined selection criteria, thereby conserving power and increasing the operating life of such sensors.

8. The bottomhole assembly of claim 1, wherein the processor updates at least one of the interactive models during the drilling of the wellbore based on the downhole computed parameters of interest.

9. The bottom hole assembly of claim 1 further comprising a plurality of devices selected from a group consisting of (a) a mud motor, (b) a thruster, (c) a steering device, and (d) a jet intensifier.

10. The bottom hole assembly of claim 9, wherein the processor controls the operation of the devices in the BHA.

11. The bottom hole assembly of claim 1 further comprising a two way telemetry system, said telemetry providing communication of data and signals between the BHA and a surface computer.

12. A drilling system for drilling an oilfield wellbore, comprising:

(a) a drill string having a bottom hole assembly ("BHA"), said bottom hole assembly comprising;

(i) a drill bit at an end of the BHA;

(ii) a plurality of sensors disposed in the BHA, each said sensor making measurements during the drilling of the wellbore relating to a parameter of interest;

(iii) a plurality of interactive models associated with the BHA, each said model adapted to manipulate data to provide a specific result; and

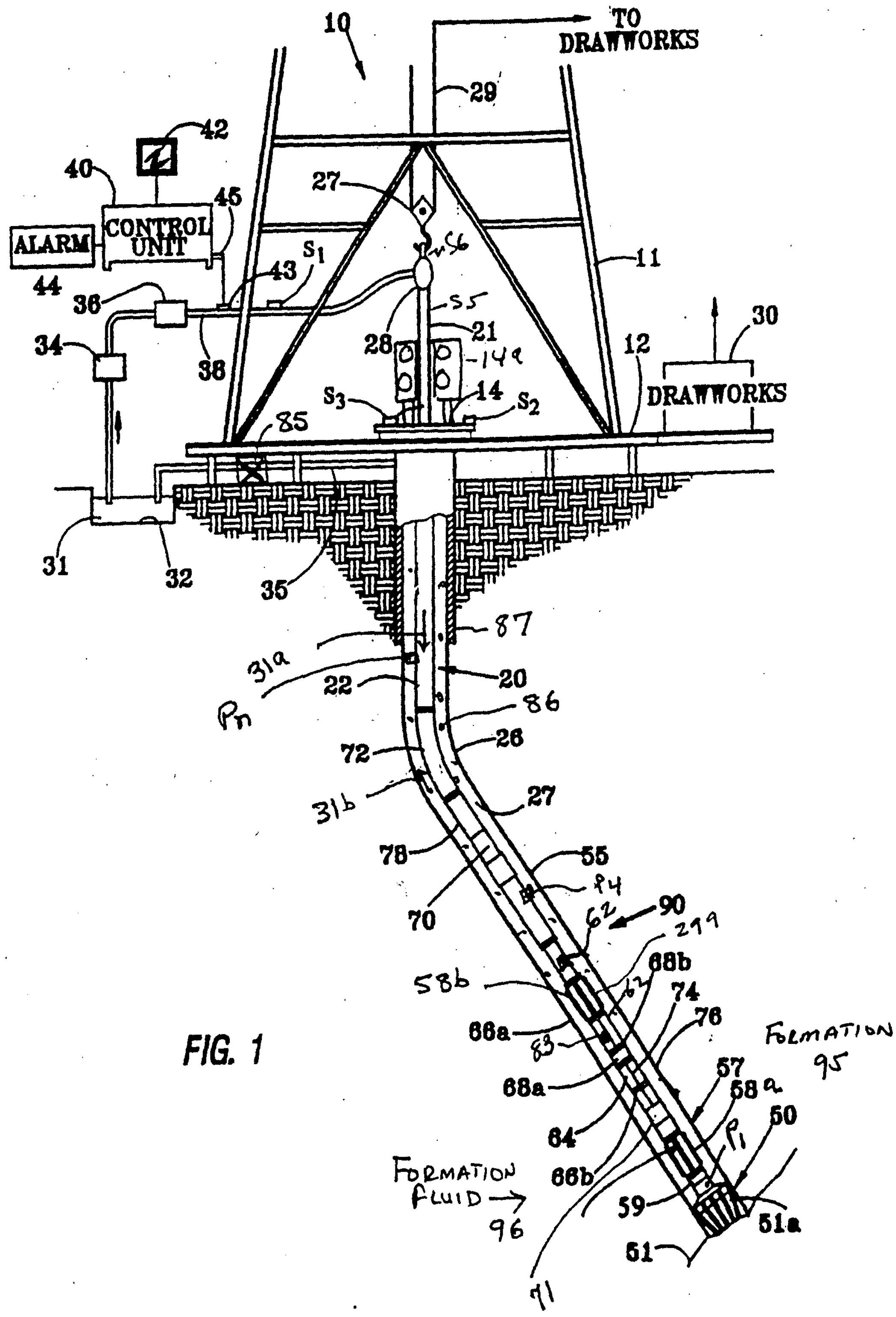
(iv) a processor in the BHA, said processor utilizing the plurality of models to manipulate the measurements from the plurality of sensors to determine a plurality of parameters of interest downhole during the drilling of the wellbore; and

(b) a transmitter associated with the BHA for transmitting data to the surface; and

(c) a computer at the surface, said computer receiving said data from the BHA and in response thereto adjusting at least one drilling parameter at the surface.

13. The system of claim 12, wherein the parameters of interest include a desired measure of at least one drilling parameter that will provide drilling of the wellbore at enhanced rate of penetration.

14. The system of claim 13, wherein the surface computer adjusts a device at the surface in response to the measure of the drilling parameter to achieve the drilling of the wellbore at the enhanced rate of penetration.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CONTROL UNIT
ALARM
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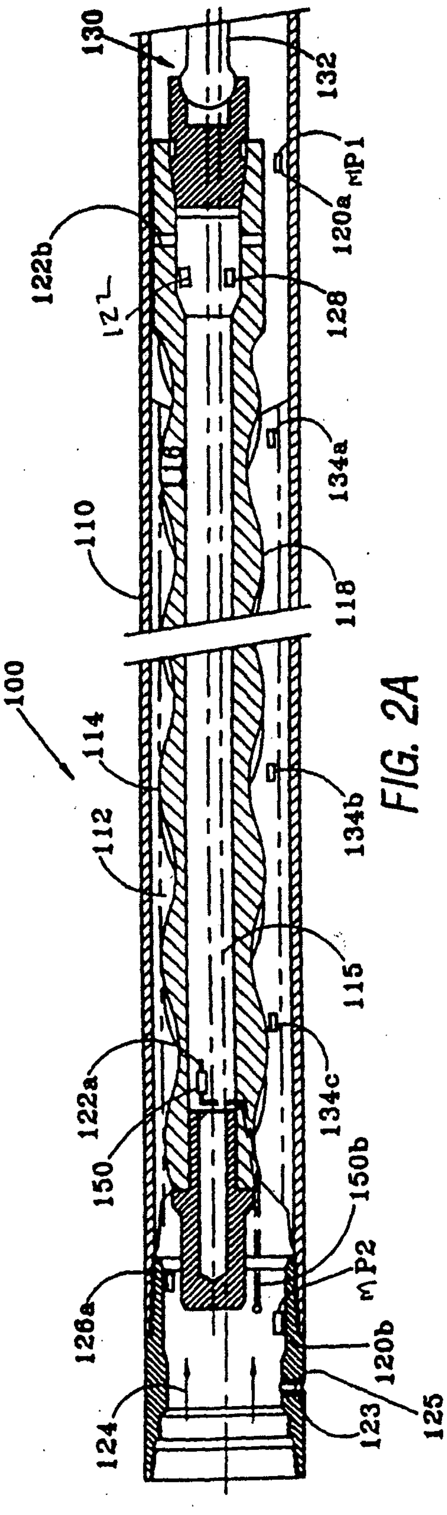
FORMATION 95
FORMATION FLUID 96

FIG. 1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150b
P2
126a
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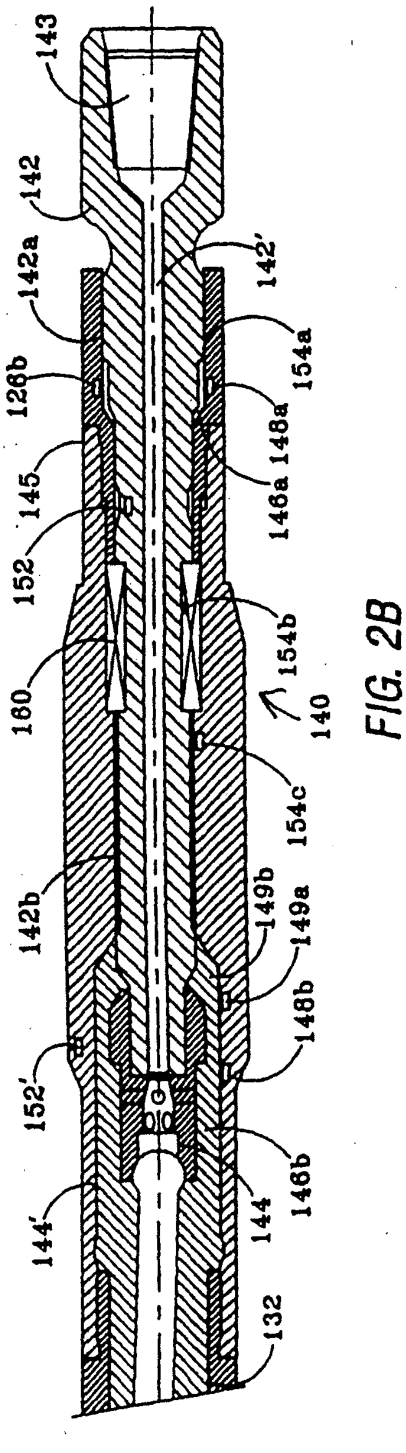
125

FIG. 2A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132

FIG. 2B

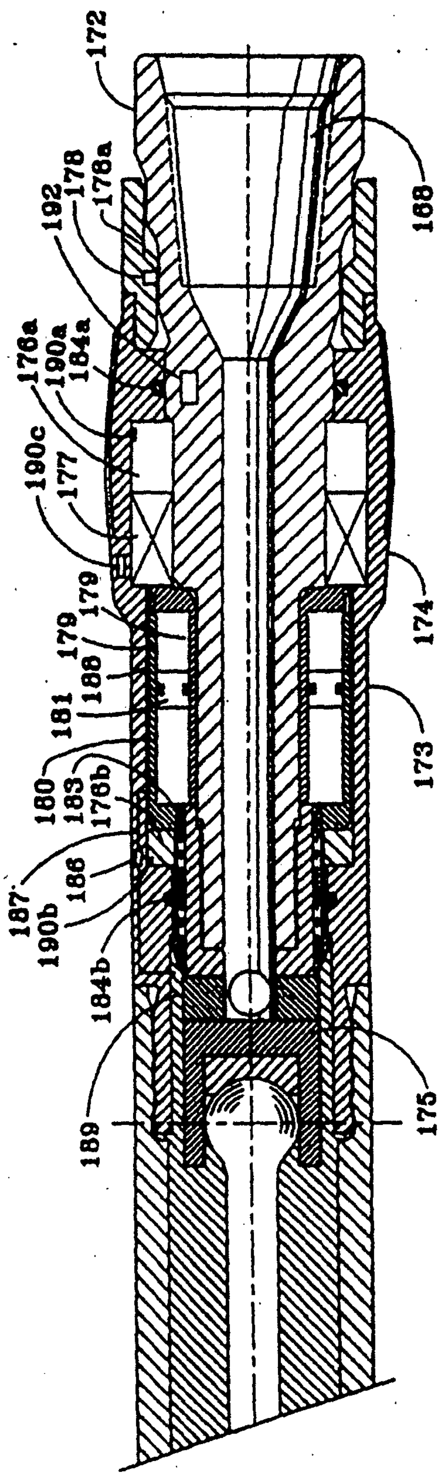
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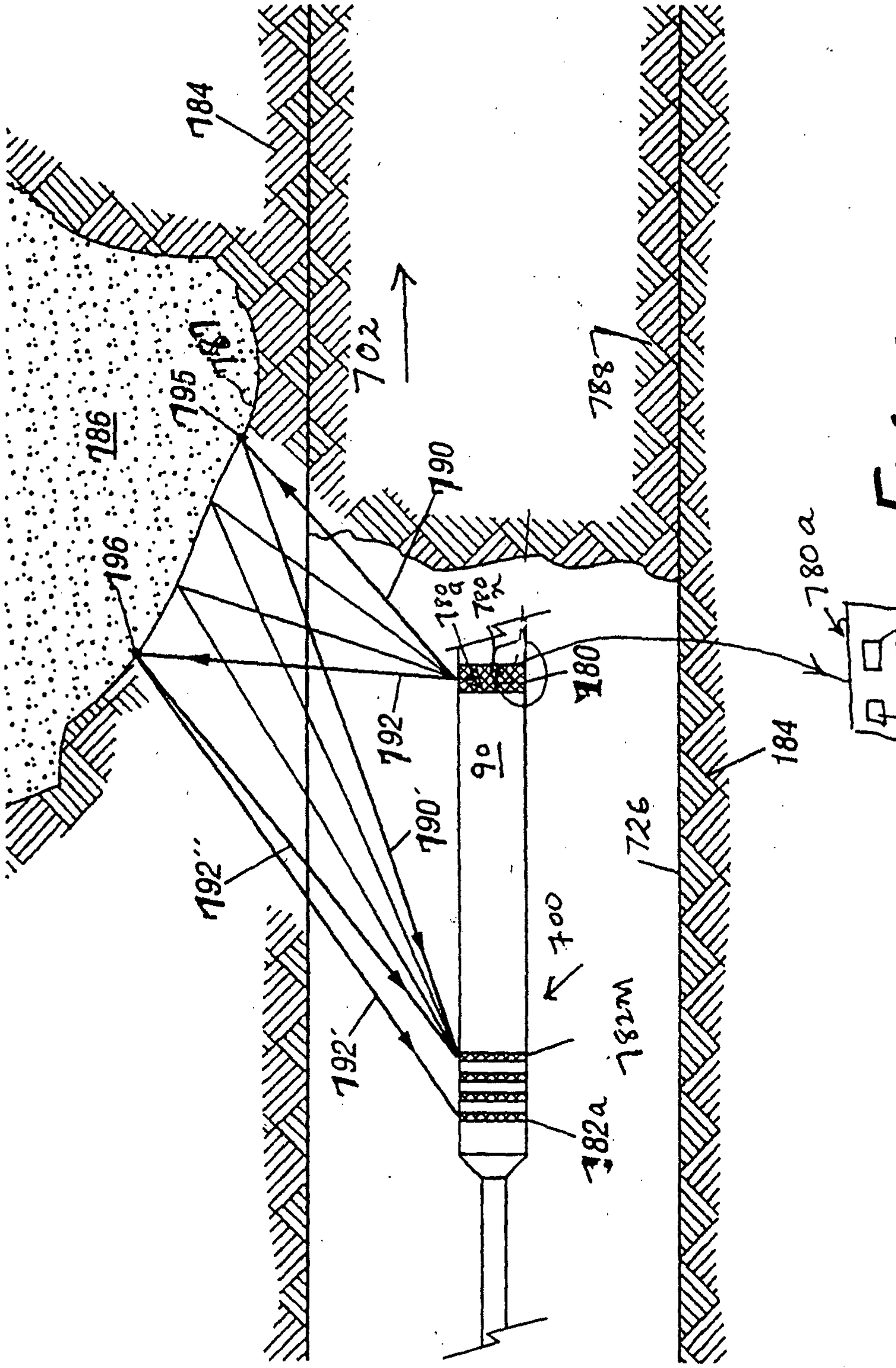
FIG. 2C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782M
782a

FIG. 9